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UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)*(Only for new nonprovisional applications under 37 CFR 1.53(b))*Docket No.
1920/106Total Pages in this Submission
28**TO THE ASSISTANT COMMISSIONER FOR PATENTS**Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

PASSIVE BALUN FET MIXER

and invented by:

Philip Piro
Kevin Cornman**If a CONTINUATION APPLICATION, check appropriate box and supply the requisite information:**☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: _____

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Enclosed are:

Application Elements

1. ☐ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 14 pages and including the following:
 - a. ☒ Descriptive Title of the Invention
 - b. ☒ Cross References to Related Applications *(if applicable)*
 - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
 - d. ☐ Reference to Microfiche Appendix *(if applicable)*
 - e. ☒ Background of the Invention
 - f. ☒ Brief Summary of the Invention
 - g. ☒ Brief Description of the Drawings *(if drawings filed)*
 - h. ☒ Detailed Description
 - i. ☒ Claim(s) as Classified Below
 - j. ☒ Abstract of the Disclosure

UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity)

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Application Elements (Continued)

3. ☒ Drawing(s) (when necessary as prescribed by 35 USC 113)
- a. ☐ Formal Number of Sheets _____
- b. ☒ Informal Number of Sheets 7
4. ☒ Oath or Declaration
- a. Newly executed (original or copy) ☒ Unexecuted
- b. ☐ Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional application only)
- c. ☒ With Power of Attorney ☐ Without Power of Attorney
- d. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application,
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference (usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche (Appendix)
7. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all must be included)
- a. ☐ Paper Copy
- b. ☐ Computer Readable Copy (identical to computer copy)
- c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☐ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(B) Statement (when there is an assignee)
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☒ Certificate of Mailing
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(Only for new nonprovisional applications under 37 CFR 1.53(b))

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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)

16. ☐ Additional Enclosures (please identify below):

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	17	- 20 =	0	x \$18.00	\$0.00
Indep. Claims	3	- 3 =	0	x \$78.00	\$0.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$690.00
OTHER FEE (specify purpose)					
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Signature

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CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10)Applicant(s): **Piro et al.**

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Group Art Unit

Not Yet Assigned

Invention: **PASSIVE BALUN FET MIXER**jc498 U.S. PTO
09/592813
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Attorney Docket: 1920/106
PASSIVE BALUN FET MIXER

Priority

5 This application claims priority from U.S. provisional application serial number 60/139,679 filed June 16, 1999, entitled "Passive Balun FET Mixer" which is incorporated herein, by reference.

Technical Field

10 The present invention relates to mixer circuits, of the type having inputs for local oscillator (LO) and radio frequency (RF) signals and an intermediate frequency (IF) output, and in particular to mixer circuits using field effect transistors (FETs).

Background Art

15 Mixers are contained in many radio transmitters, receivers, and other communication devices. Such mixers operate by combining an RF signal with LO, a periodic signal, producing a mixed output. This mixed output contains signals whose frequencies consist of either the sum or difference between RF and LO frequencies. By filtering the mixed output, an IF signal can be created whose frequency is either higher or lower than the original RF frequency.

20 As a result of the desire to decrease the size of communication devices, mixer size must also be reduced. Double balanced diode mixers, widely used in the industry, are large. By utilizing FETs instead of diodes, and removing the multiple baluns, size can be reduced without sacrificing performance.

25 Passive floating FET mixers are known in the art. A floating FET configuration uses an electrically symmetrical FET, whose drain and source terminals float with respect to ground and are coupled to the output port via a balun, as described in Vasile, C. F., Floating GASFET Circuits Offering Unique Signal Processing from DC-EHF, 1985 GOMAC Proceedings, Pp.305-309, 1985, incorporated herein by reference in it's entirety. Fig.1, taken from Vasile's article, shows a single floating FET configuration. An alternative floating FET configuration

which replaces the single transistor with two transistors in series is shown in Fig. 2, also taken from Vasile's article. U.S. patent 4,705,967, issued for an invention of Vasile and incorporated herein by reference in its entirety, discloses a floating multifunction FET circuit that may be used as a mixer, as shown in Fig. 3. The IF is
5 extracted from the same side of the balun 328 as the RF signal. Therefore, the balun in this design must be large to account for both the higher frequency RF signal and the lower frequency IF signal. Additionally, the RF and IF signals are not isolated, resulting in possible distortion of these signals.

Mourant, in US. patent 5,697,092 and in "A Low cost Mixer for Wireless
10 Applications," 1995 IEEE Microwave Systems Conference pp. 21-24, also discloses similar subject matter pertaining to passive floating FET mixers, each of which is hereby incorporated herein by reference in its entirety. In U.S. patent 5,697,092, a single, floating FET mixer suitable for compact construction is disclosed, as shown in Fig. 2, taken from Mourant. The balanced IF created in the FET mixer is extracted at
15 the RF balun in an unbalanced manner, being diplexed from the balun center tap. A series inductor 414 and capacitor 415 resonates at the RF frequency and shorts out center tap 412 to ground 406. At low frequencies, the capacitor is an open, allowing the IF 416 to be extracted. The balun is fabricated with primary and secondary windings consisting of planar metal spirals that are interleaved with one another, as
20 described by Mourant, col. 4, lines 11-18. One problem with this design is that adding a centertap to a balun adds steps to the manufacturing process. Additionally, the centertap position must be located, requiring calculation and testing. Another problem is that the IF output leads must cross over portions of the interleaved windings, making it susceptible to parasitic capacitance.

Summary of the Invention

In accordance with one aspect of the invention, a FET mixer uses a balun having a primary and secondary, with the primary coupled to an RF signal input. The mixer also includes a pair of field effect transistors (FETs), wherein the gates are coupled to one another and to a local oscillator input. One of the source and the

capacitance that serves as a shunt at the frequency of the RF signal but not at the frequency of the intermediate signal. In another related embodiment, a capacitance is applied across the balun primary to tune the primary. A capacitance may optionally be applied across the balun secondary to tune the secondary, which may
5 include a pair of capacitors in series, wherein the node at a connection between the capacitors is coupled to ground. In another related embodiment, ground is coupled to the center tap of the balun secondary.

In another embodiment, a FET mixer uses a transformer, having a primary and secondary, the primary coupled to an RF signal. The mixer also has a pair of
10 switches, comprising of a first switch and a second switch, wherein the gates of the switches are coupled to one another and to a periodic signal input. The first switch is coupled at a node to ground, and the node is coupled to the second switch.

Additionally, one switch is attached to one side of the secondary of the transformer, and the other switch is attached to the other side of the secondary of the

15 transformer. An intermediate frequency signal output is coupled to a point in the circuit path between the first and second transistor. In a further related

embodiment, at the node, one of the switches is connected to ground, and the node is coupled to the other switch by means of a filter. The filter may have a capacitor that serves as a shunt at the frequency of the RF signal but not at the frequency of

20 the intermediate frequency signal. In another related embodiment, tuning circuitry is disposed across the transformer's secondary, and may include a pair capacitors in series, wherein the node at a connection between the capacitors is coupled to

ground. In another related embodiment, the secondary of the transformer has a center tap, which is coupled to ground. In another related embodiment, tuning

25 circuitry is disposed across the primary of the transformer.

Brief Description of the Drawings

The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

Fig. 1a shows a prior art single floating FET configuration, as shown in U.S. patent 4,705,967.

Fig. 2 shows a prior art series connected floating FET configuration, as shown in U.S. patent 4,705,967.

5 Fig. 3 is a schematic view of a prior art single FET mixer, as shown in U.S. patent 4,705,967.

Fig. 4 is a schematic view of a prior art single FET mixer, as shown in U.S. patent 5,697,092.

10 Fig. 5 is a block diagram of a passive balun FET mixer in accordance with an embodiment of the present invention.

Fig. 6 is a schematic view of a passive balun FET mixer in accordance with an embodiment of the present invention.

Fig. 7 is a schematic view of a minimum configuration of the passive balun FET mixer in accordance with an embodiment of the present invention.

15 Fig. 8 is a flowchart depicting a method of mixing a periodic signal and a radio frequency signal producing an intermediate frequency.

Detailed Description of Specific Embodiments

For the purposes of the description herein and the claims that follow it, unless the context otherwise requires, the term "Radio Frequency" (RF) means an
20 electromagnetic signal at frequencies in the range extending from below 3 kilohertz to 300 gigahertz, which includes radio and television transmission. These frequencies are above audio signals and below the frequencies of visible light. The term "intermediate frequency" (IF) shall mean the frequency that an incoming signal is changed to. The term "local oscillator" (LO) shall mean a periodic signal. The term
25 "balun" shall mean a transformer connected between a balanced source or load and an unbalanced source or load. A balanced line has two conductors, with equal currents in opposite directions. The unbalanced line has just one conductor; the current in it returns via a common ground or earth path.

Fig. 5 is a block diagram of the passive balun FET mixer in accordance with

Q2 are at ground potential, and thus neither Q1 nor Q2 is a floating FET.

A tuning capacitor C5 is placed across the terminals of the primary winding of TX1. Capacitors C3 and C4 tune the secondary winding. Capacitors C3 and C4 may optionally be replaced by a single capacitor in shunt across the secondary of TX1, with the risk that the signals on Q1 and Q2 may be less balanced.

The secondary may be optionally center-tapped as shown in Fig. 6. The midpoint of the secondary is coupled to ground through capacitor C6 in order to provide better symmetry in the RF signal at the drains of transistors Q1 and Q2. If the center tap is not used, then capacitor C6 is not necessary.

Capacitor C1 allows for passive self-biasing of the FETs near pinch-off voltage due to rectification of the positive half cycle of LO voltage. As a result, no external biasing is required. Capacitor C1 is charged with the gate side at a negative potential relative to the LO side of the capacitor. Then on the negative half cycle, the lower LO voltage in combination with the charge on C1 keeps each FET from conducting. The LO signal modulates the channel resistance of the FETs from a minimum value when V_{gs} is approximately zero volts to a maximum value at voltage less than $-V_{pinch\ off}$. The time-varying resistances of the channels of Q1 and Q2 terminate the RF circuit, which includes the transformer TX1 and tuning capacitors C3, C4, and C5. These time-varying resistances, which vary at the rate of the LO frequency, effect the conversion of the RF signal to new signals at frequencies that equal the sums and differences of the LO and RF frequencies and their integer multiples.

The signal corresponding to the difference between the LO and RF frequency is known as the intermediate frequency (IF). The IF signal is conveniently retrieved between transistors Q1 and Q2, instead of at the centertap of the balun. Capacitor C2 acts as a low pass filter to reject higher frequency signals and to allow only the IF to pass through to the IF output.

Fig. 7 shows a minimum configuration of the passive balun FET mixer shown in fig. 6, in accordance with an embodiment of the present invention. Optional

tuning capacitors C3, C4, and C5 capacitors and coupling capacitor C1 have been removed. The mixer includes two FET transistors, Q1 and Q2. The drains of Q1 and Q2 are connected to the secondary winding of a transformer TX1 acting as a balun. The mixer also includes the IF bypass capacitor C2.

5 Fig. 8 shows a method of mixing a periodic signal and a radio frequency signal producing an intermediate frequency. RF is applied to a primary of a balun (step 804), isolating RF from the balun secondary. A periodic signal is applied to a first and second switch, each switch coupled to the other switch, and also attached to a secondary of the balun (step 806). The periodic signal simultaneously turns on and
10 off each transistor periodically, resulting in multiplication of the RF and periodic signals. A mixed signal is thus created, consisting of frequencies equal to the sum and difference of the RF and periodic signal frequencies. A filter is applied to the mixed output between the first and second switch to obtain the intermediate frequency (step 808). Utilizing a low pass filter, the higher frequency component of
15 the mixed signal is shunted to ground, resulting in down-frequency translation of the RF signal. Alternatively, utilizing a high pass filter will result in up-frequency translation of the RF signal.

In one embodiment of the present invention, the passive balun FET mixer is operable at RF frequencies in the multi-gigahertz range, although this invention will
20 operate in other RF ranges. At these multi-gigahertz frequencies, capacitances are typically in the approximate range of 1-20 pF, with capacitor C2 being of the order of 15 pF, and all other capacitances less than 5 pF. The FETs Q1 and Q2 may be realized as Metal-Semiconductor Field Effect Transistors (MESFETs), which are FETs fabricated of gallium arsenide (GaAs) and formed with a metal-semiconductor
25 junction. The use of MESFETs is not intended to limit the scope of the invention and other types of FETs may be used.

Although various exemplary embodiments of the invention have been disclosed, it should be apparent to those skilled in the art that various changes and modifications can be made which will achieve some of the advantages of the

invention without departing from the true scope of the invention. These and other obvious modifications are intended to be covered by the claims that follow.

What is claimed is:

1. A field effect transistor mixer comprising:
 - a. a balun having a primary and a secondary, the primary coupled
5 to a radio frequency signal input;
 - b. a pair of field effect transistors, each transistor having a gate, a source, a drain, and a channel between the source and the drain, wherein
 - i. the gates of the transistors are coupled to one another
and to a local oscillator input,
 - 10 ii. one of the source and the drain of a first of the two transistors is coupled at a node to one of the source and the drain of the other of the two transistors, and the node is coupled to ground,
 - iii. the other of the source and the drain of the first of the
two transistors is coupled to one side of the secondary of the balun and the other of
15 the source and the drain of the second of the two transistors is coupled to the other side of the secondary of the balun;
 - c. and an intermediate frequency signal output coupled to a point
in the circuit path between the first and second transistors.
- 20 2. A mixer according to claim 1, wherein, at the node, one of the source and the drain of the second of the two transistors is connected to ground, and the node is coupled to one of the source and drain of the first of the two transistors by a filter.
- 25 3. A mixer according to claim 2, the filter having a capacitor serving as a shunt at the frequency of the Radio frequency signal but not at the frequency of the intermediate frequency signal.
4. A mixer according to claim 1, wherein the local oscillator input is
30 coupled to the gates via a capacitor so as to cause the transistors to be biased near pinch off.

5. A mixer according to claim 1, further comprising a capacitance disposed across the balun secondary to tune the secondary.

6. A mixer according to claim 5, wherein the capacitance includes a pair of capacitors connected in series, wherein the node at a connection between the capacitors is coupled to ground.

7. A mixer according to claim 1, wherein the secondary has a center tap, and the center tap is coupled to ground.

8. A method of mixing a periodic signal and a radio frequency signal producing an intermediate frequency signal, the method comprising:
applying the radio frequency signal to a primary of a balun;
applying a periodic signal simultaneously to a first and a second switch, each switch coupled to the other switch and also coupled to a secondary of the balun, resulting in a frequency translation of the periodic signal and the radio frequency signal producing a mixed output; and
outputting the intermediate frequency signal by filtering the mixed output between the first and second switch.

9. A method according to claim 8, wherein the step of outputting the intermediate signal by filtering the output between the first and second switch includes coupling one switch at a node to ground, and coupling the other switch to the node by a filter.

10. A method according to claim 8, wherein the step of filtering of the mixed output includes applying a capacitance that serves as a shunt at the frequency of the Radio frequency signal but not at the frequency of the intermediate signal.

11. A method according to claim 8, further comprising applying a capacitance across the balun primary to tune the primary.

12. A method according to claim 8, further comprising applying a capacitance across the balun secondary to tune the secondary.

13. A method according to claim 12, wherein the capacitance includes a pair of capacitors in series, wherein the node at a connection between the capacitors is coupled to ground.

14. A method according to claim 8, further comprising coupling ground to the center tap of the balun secondary.

15. A field effect transistor Mixer comprising:

- a. a transformer having a primary and a secondary, the primary coupled to a Radio frequency signal;
- b. a pair of switches, comprising of a first switch and a second switch, wherein
 - i. the gates of the switches are coupled to one another and to a periodic signal input,
 - ii. the first switch is coupled at a node to ground, and the node is coupled to the second switch,
 - iii. one switch is attached to one side of the secondary of the transformer, and the other switch is attached to the other side of the secondary of the transformer; and
- c. an intermediate frequency signal output coupled to a point in the circuit path between the first and second transistors.

16. A mixer according to claim 15, wherein, at the node, one of the switches is connected to ground, and the node is coupled to the other switch by a filter.

17. A mixer according to claim 16, the filter having a capacitor serving as a shunt at the frequency of the Radio frequency signal but not at the frequency of the intermediate frequency signal.

Attorney Docket: 1920/106
PASSIVE BALUN FET MIXER

Abstract

5 A FET mixer uses a balun having a primary and secondary, with the primary
coupled to an Radio frequency signal input. The mixer also includes a pair of field
effect transistors (FETs), wherein the gates are coupled to one another and to a local
oscillator input. One of the source and the drain of the second of the two transistors
is coupled at a node to one of the source and the drain of the other of the two
10 transistors, and the node is coupled to ground. The other of the source and the drain
of the first of the two transistors is coupled to one side of the secondary of the balun
and the other of the source and the drain of the second of the two transistors is
coupled to the other side of the secondary of the balun. An intermediate frequency
signal output is coupled to a point in the circuit path between the first and second
transistors.

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The diagram shows a mixer circuit 374. An LO IN signal enters at point A, passing through a capacitor and a series inductor to the base of a transistor 320. The transistor's emitter is connected to a common ground line. A biasing network consisting of a battery 392 and a capacitor is connected to the common ground line at point B. The collector of transistor 320 is connected to a double-balanced mixer core 348. This core contains two diodes 350 and two capacitors. An RF SOURCE is connected to the mixer core at point E. The output of the mixer core is taken from point G, which is labeled IF OUT. The output path includes a series inductor 370 and a shunt capacitor 372 connected to the common ground line. The entire circuit is enclosed in a dashed box labeled MIXER 374.

Fig. 3
Prior Art

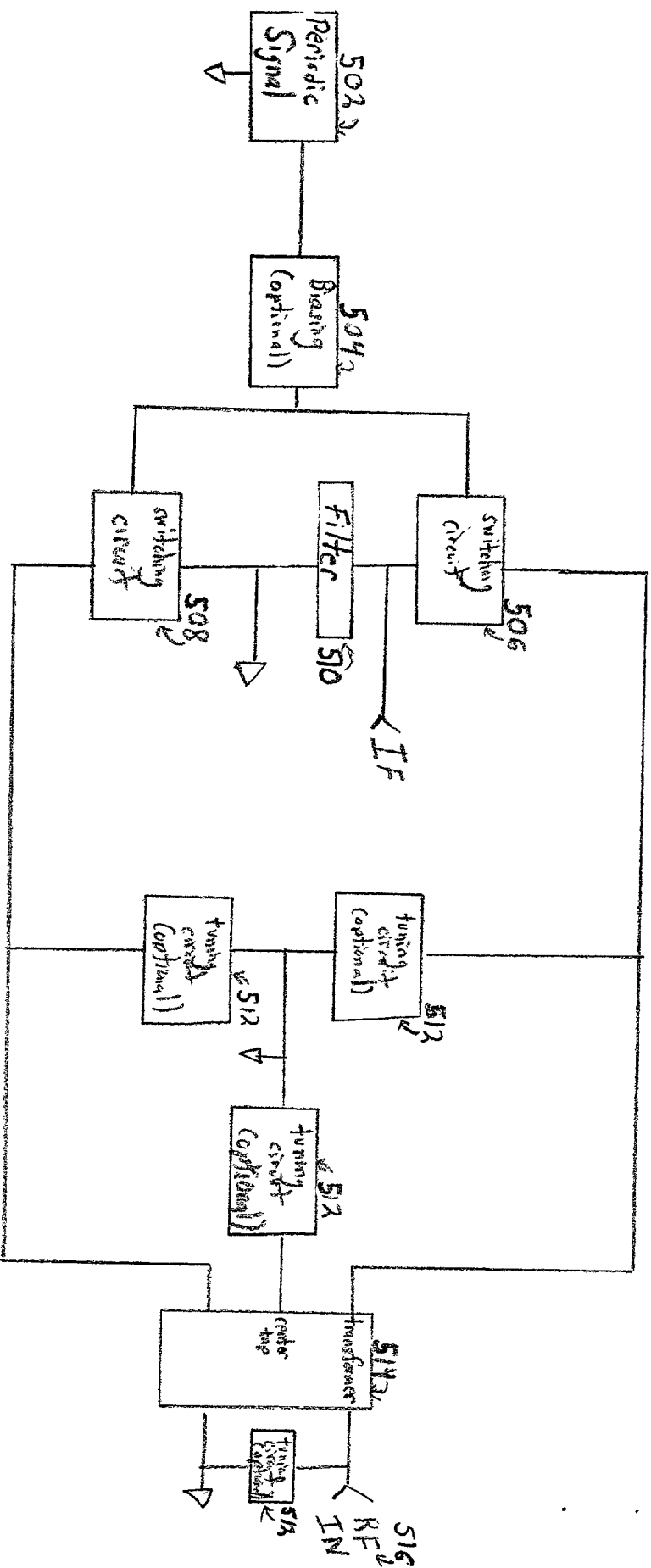


Figure 5

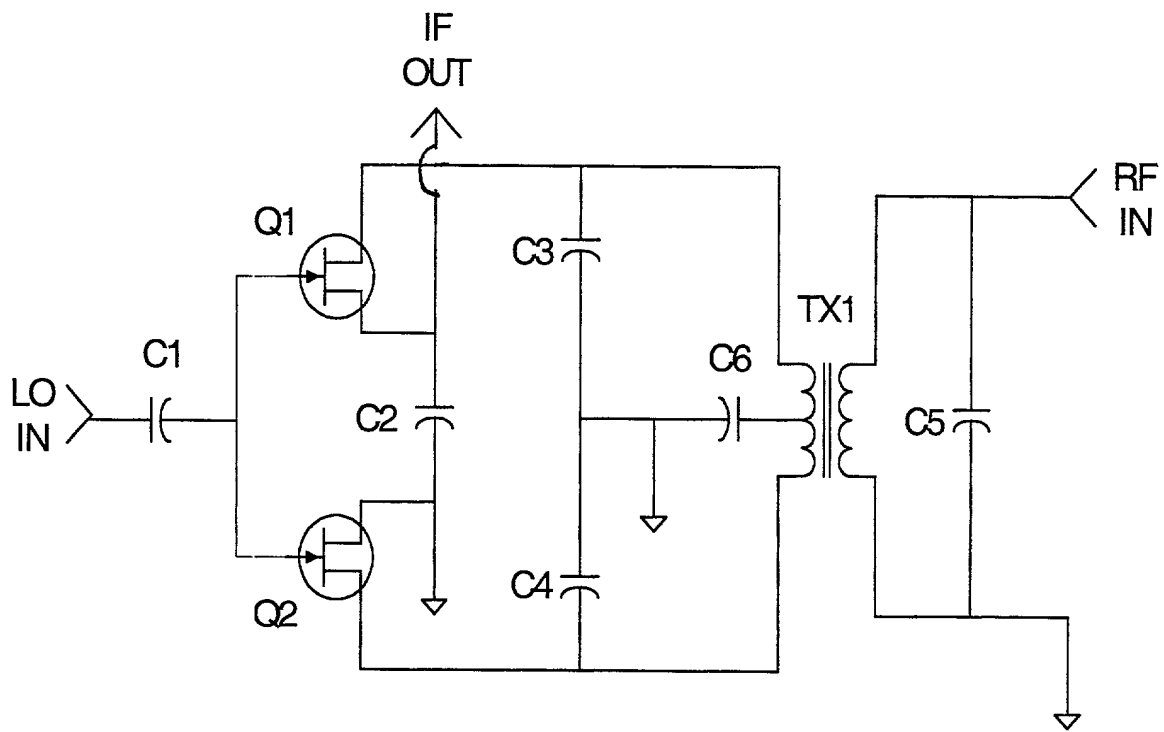


Figure 6

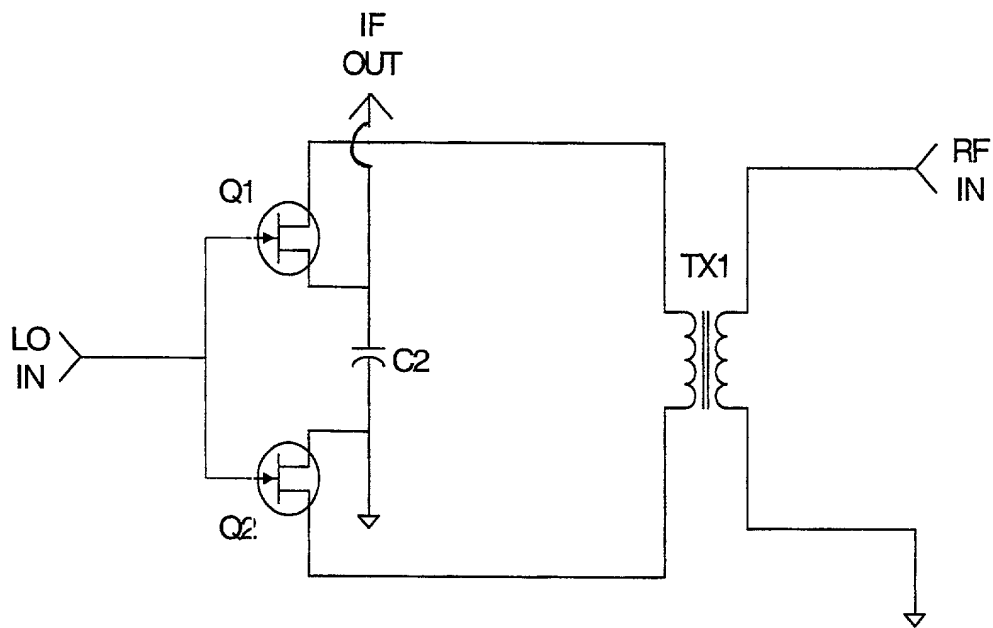


Figure 7

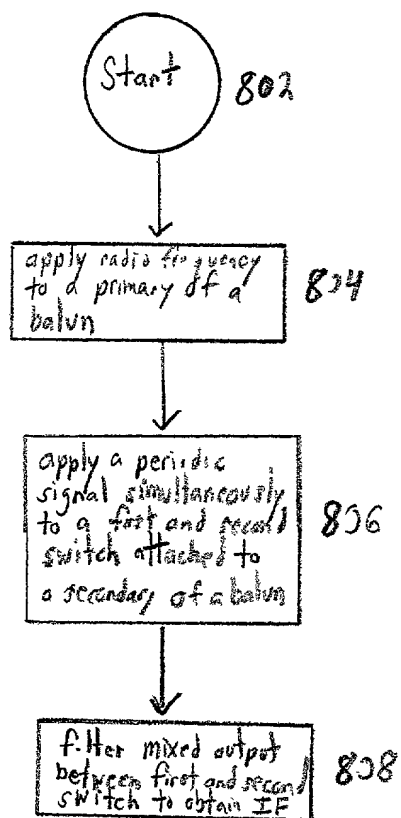
[illegible]

Figure 8

Docket No.
1920/106

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

PASSIVE BALUN FET MIXER

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International

Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

60/139,679	June 16, 1999
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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